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RESEARCH MEMORANDUM

for the

U. S. Air Force

INVESTIGATION OF INCIPIENT SPIN CHARACTERISTICS OF A 1/35-SCALE MODEL OF THE CONVAIR F-102A AIRPLANE

COORD. NO. AF-AM-79

By Frederick M. Healy

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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SUMMARY

Incipient spin characteristics have been investigated on a 1/35-scale dynamic model of the Convair F-102A airplane. The model was launched by a catapult apparatus into free flight with various control settings, and the motions obtained were photographed. The model was ballasted for the combat loading. All tests were made with the speed brakes and landing gear retracted, and engine effects were not simulated.

The results of the investigation indicated that the model would enter motions apparently simulating entry phases of spins when the elevators were deflected full up. Deflecting the rudder had little effect on the direction of the motion obtained, but when ailerons were deflected the model always rotated in a direction opposite to the aileron setting (that is, the model entered a right spin with the stick to the left). The ailerons were very influential in initiating spin entry, and the pilot should avoid, as far as possible, the use of ailerons in low-speed flight.

INTRODUCTION

At the request of the U. S. Air Force, an investigation has been made of the incipient spin characteristics of a 1/35-scale model of the Convair F-102A airplane on a catapult at the Langley Laboratory. The F-102A is a jet-propelled, delta-wing, single-seat fighter airplane.

The model was launched at the steepest glide-path angle obtainable on the catapult at the angle of attack and airspeed corresponding to this glide path and also at the angle of attack required for trim with full-up elevator, with various control dispositions. Motion pictures were made of the ensuing flights. The model was ballasted for the combat loading. Speed brakes and landing gear were not simulated on the model. No provision was made on the model to simulate engine thrust or gyroscopic effects, or to deflect the control surfaces during flight.

SYMBOLS

b	wing span, ft
S	wing area, sq ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slug/cu ft
q	dynamic pressure, $\frac{1}{2}\rho V^2$

μ relative density of airplane, $\frac{m}{\rho S b}$

α angle of attack, deg

γ glide-path angle, deg

V resultant velocity of center of gravity, ft/sec

δ_e elevator deflection, deg

δ_a aileron deflection, deg

δ_r rudder deflection, deg

C_L lift coefficient, $\frac{\text{Lift}}{qS}$

APPARATUS AND METHODS

Model

The 1/35-scale model of the Convair F-102A airplane was furnished by the U. S. Air Force. A three-view drawing of the model as tested is shown in figure 1. The dimensional characteristics of the airplane are presented in table I.

Longitudinal and lateral control of the airplane and model are obtained from deflection of one set of control surfaces called elevons. Hereinafter, elevon deflections for longitudinal and lateral control are referred to, for simplicity, as elevator deflection and aileron deflection, respectively.

Testing Technique

The technique employed for the tests was generally similar to that described in reference 1. The launching apparatus was located inside a building, approximately 55 feet above the floor. The catapult consisted of a carriage propelled along a track by a shock chord, accelerating the model to the launching velocity. The velocity was measured by an electronic timing device. The model was retrieved by a large net hung from the wall opposite the catapult. The tests were recorded by motion pictures taken in line with the flight path from behind the apparatus, and from the side of the building at approximately right angles to the flight path.

TEST CONDITIONS AND PRECISION

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho = 0.001496$ slug/cu ft). The mass characteristics of the airplane and model are presented in table II.

The maximum control-surface deflections used on the model during the tests (measured perpendicular to the hinge lines) were:

Rudder, deg	25 right, 25 left
Elevator, deg	25 up, 0
Ailerons, deg	7 up, 7 down

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the F-102A model varied from the true scaled-down values within the following limits:

Weight, percent	1 high to 3 high
Center-of-gravity location, percent $\bar{c}$	0 to 1 rearward
Moments of inertia:	
I_X, percent	17 high to 25 high
I_Y, percent	2 low to 7 high
I_Z, percent	4 low to 4 high

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls are set with an accuracy of $\pm 1^{\circ}$.

RESULTS AND DISCUSSION

The results of the investigation were recorded by visual observation and motion pictures and are qualitative in nature. The discussion presented herein summarizes the trends observed for various control deflections during a large number of flights. The model was launched at the maximum glide-path angle to which the track of the catapult apparatus could be depressed (14.5°). Some brief tests were made with the model angle of attack set at 16° and the elevator placed at 7° up (lateral and directional controls neutral) to give the lift coefficient required to maintain this glide path. In addition, the model was launched at an angle of attack of 16° with full-up elevator, the excess pitching moment thereby obtained causing the model to enter an accelerated stall. For other tests the model was launched at the stall angle of attack (35°) with full-up elevator, the amount of elevator required for trim at the stall for the center-of-gravity position tested. Figure 2 shows the trim angle of attack for a given glide-path angle. Elevator deflection, lift coefficient, and resultant velocity of the model at launch required for trimmed flight are given in figure 3 as a function of angle of attack. Figures 2 and 3 are based on information received from the contractor.

When the model was launched in trim at an angle of attack of 16°, the model remained in a trimmed glide. For the other cases investigated, however, the results indicate that motions apparently representing entry into spins could be obtained. Due to space limitations, usually only one-half to one turn of directional change could be observed, but the motions were characteristically those of a spinning model. The model was most prone to spin when the accelerated stall method of entry was used. As was pointed out previously, accelerated stalls were obtained when the model was launched at an angle of attack of 16° with full-up elevator (35°). The rudder had little effect in determining the direction in which the model rotated but it appeared that spins were more readily obtainable when ailerons were deflected than when ailerons were neutral. In all cases with ailerons deflected the spin-entry motions observed were such that the rotation of the model was opposite to aileron deflection (that is, the model entered a right spin with stick to the left). The pilot should be cognizant of the influence of ailerons in initiating spin entry, and should avoid as far as possible the use of ailerons in attempting to maintain wings-level flight in the extreme low-speed flight region. The effect of aileron setting on spins and recoveries of current airplane types is discussed more fully in references 2 and 3.

CONCLUDING REMARKS

Based on the results of an investigation on a catapult at the Langley Laboratory, the following statements regarding the incipient spin characteristics of the Convair F-102A airplane with speed brakes and landing gear retracted at an altitude of 15,000 feet are made: The airplane will enter spins at full-up elevator, and will be most prone to spin when entry is made from an accelerated stall. Rudder deflection will have little effect on the direction of spins obtained, but the airplane will spin in a direction opposite to that to which the ailerons are deflected (that is, spin to the right when the stick is to the left). The ailerons are influential in initiating spin entry and the pilot should avoid as far as possible the use of ailerons in low-speed flight.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 29, 1958.

REFERENCES

1. Stone, Ralph W., Jr., Garner, William G., and Gale, Lawrence J.: Study of Motion of Model of Personal-Owner or Liaison Airplane Through the Stall and Into the Incipient Spin by Means of a Free-Flight Testing Technique. NACA TN 2923, 1953.

2. Neihouse, Anshal I.: Effect of Current Design Trends on Airplane Spins and Recoveries. NACA RM L52A09, 1952.

3. Neihouse, Anshal I., Klinar, Walter J., and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NACA RM L57F12, 1957.

TABLE I

DIMENSIONAL CHARACTERISTICS OF THE CONVAIR F-102A AIRPLANE

Overall length, ft	63.18
Wing:	
Span, ft	38.13
Area, sq ft	661.5
Mean aerodynamic chord, in.	285.0
Aspect ratio	2.2
Airfoil section	NACA 0004-65 (modified)
Incidence	0
Dihedral	0
Sweepback at leading edge, deg	60.10
Camber, percent	7.5
Vertical tail:	
Total area, sq ft	68.33
Fin area, sq ft	58.73
Rudder area, sq ft	9.60
Span to theoretical tip, ft	8.67
Mean aerodynamic chord, in.	126.156
Aspect ratio	1.099
Airfoil	NACA 0004-65 (modified)
Sweepback at leading edge, deg	60
Elevons:	
Area, sq ft	67.2
Span (each), ft	12.771

[redacted]

TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING OF CONVAIR F-102A AIRPLANE AND FOR LOADING TESTED ON 1/35-SCALE MODEL[a]

Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	15,000 feet	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values											
Combat	24,811	0.278	------	12.85	20.42	13,600	128,000	138,000	$-1{,}021 \times 10^{-4}$	-89×10^{-4}	$1{,}110 \times 10^{-4}$
Model values											
Combat	25,327	0.283	0.030	13.12	20.86	16,446	131,274	138,239	$-1{,}003 \times 10^{-4}$	-61×10^{-4}	$1{,}064 \times 10^{-4}$

[a]Values given are full scale, and moments of inertia are given about the center of gravity.

[redacted]

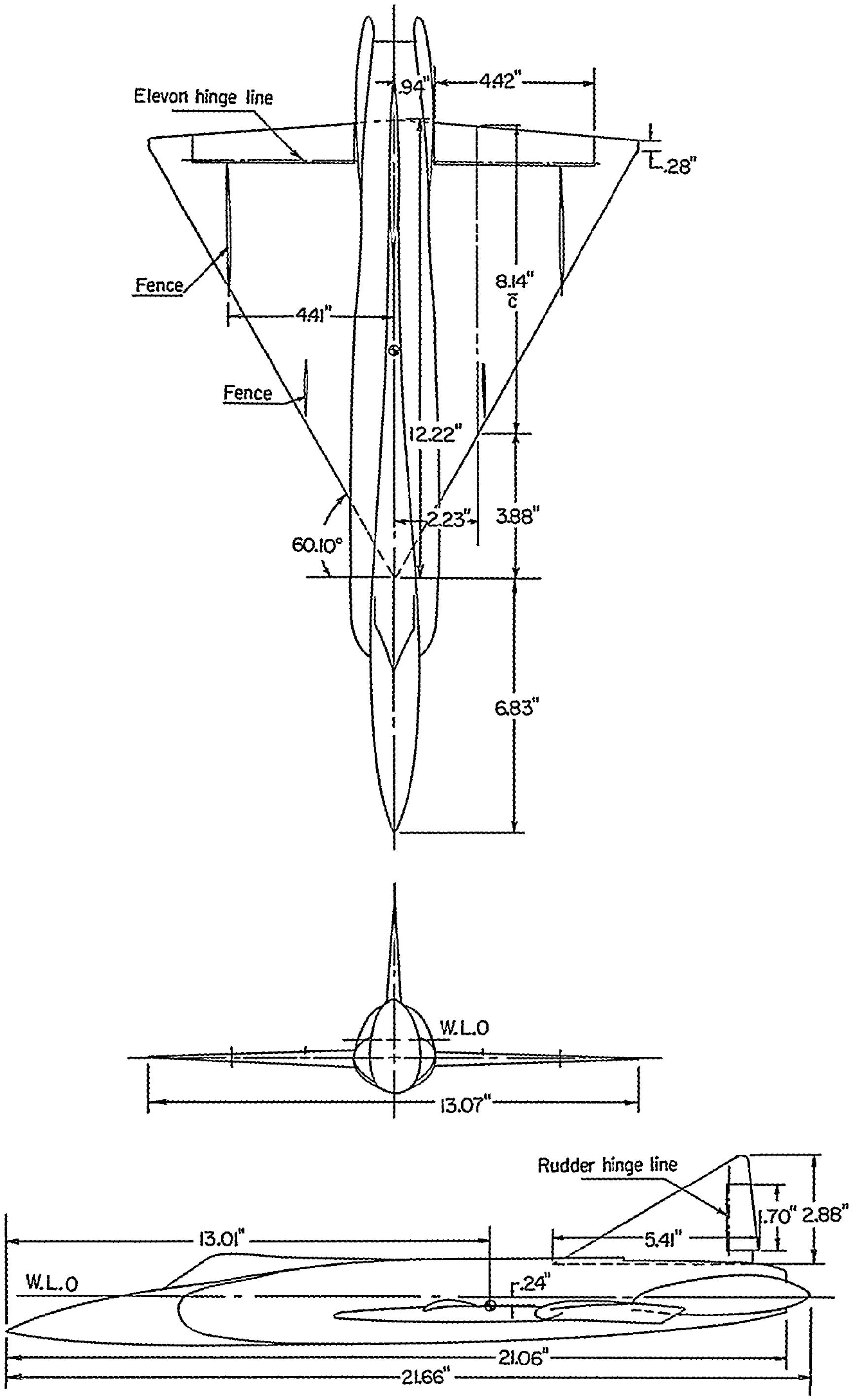

Figure 1.- Three-view drawing of 1/35-scale model of Convair F-102A airplane. Center-of-gravity position indicated is for combat loading.

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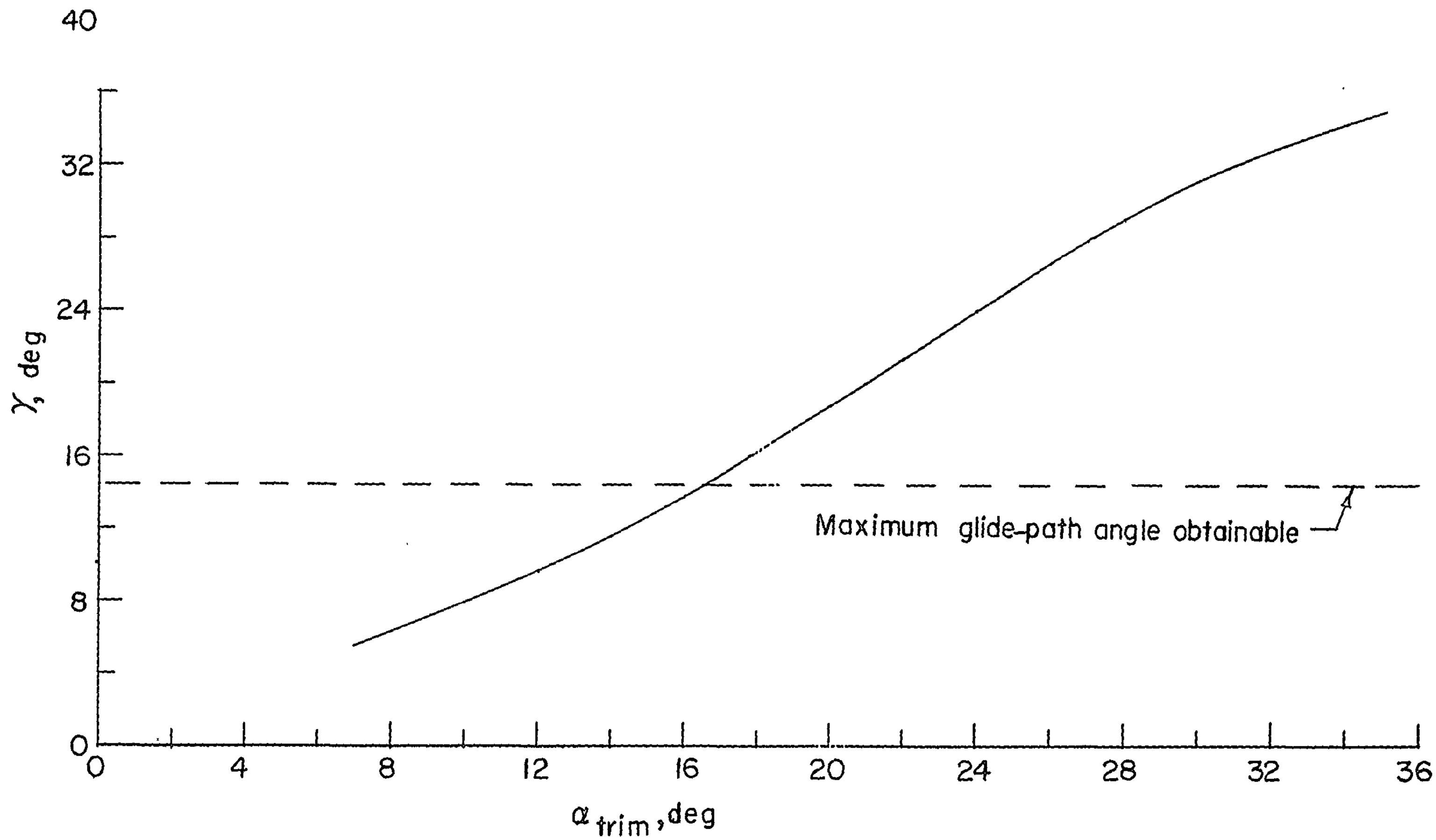

Figure 2.- Variation of glide-path angle with trim angle of attack of model at launch.

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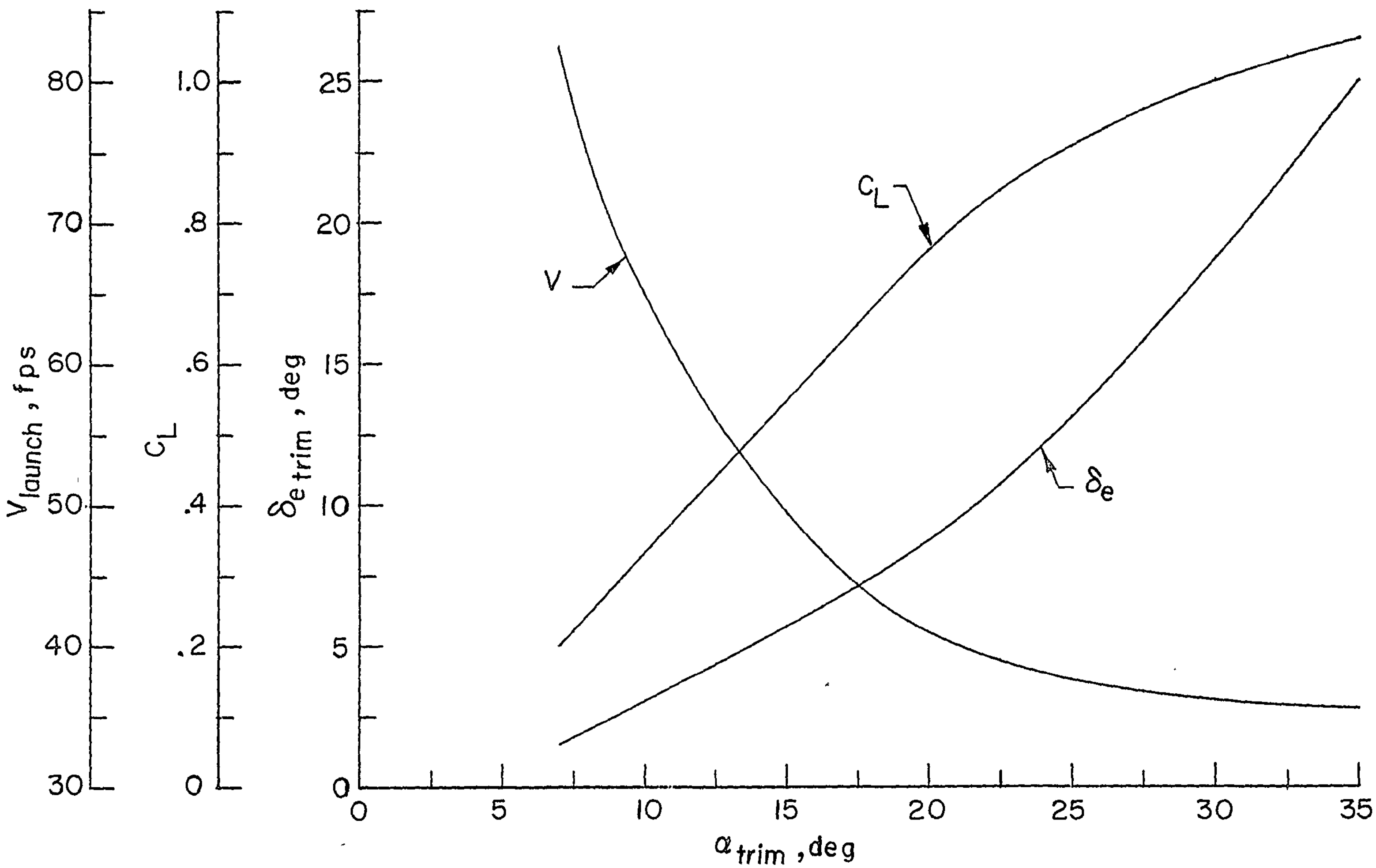

Figure 3.- Variation of elevator deflection, lift coefficient, and launching velocity required for trimmed flight with angle of attack of model at launch.

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INDEX HEADINGS

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